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PROJECT
20021601

PUMPING TEST PLAN

WINNEBAGO RECLAMATION LANDFILL
ROCKFORD, ILLINOIS

JULY 1994

PREPARED FOR:
WINNEBAGO RECLAMATION LANDFILL
ROCKFORD, ILLINOIS

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PREPARED BY:
WARZYN INC.
Madison, Wisconsin

PROJECT
20023601

PUMPING TEST PLAN

WINNEBAGO RECLAMATION LANDFILL
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JULY 1994

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INTRODUCTION

The September 1993 Groundwater Extraction and Treatment System Remedial Design Work Plan (Groundwater RD Work Plan) was developed in accordance with the Consent Decree, Statement of Work, and the Remedial Design And Remedial Action (RD/RA) Work Plan for the Winnebago Reclamation Landfill (WRL) site located in Winnebago County, Illinois. The Groundwater RD Work Plan provides Supplemental information required for the design of the groundwater extraction and treatment system described in the RD/RA Work Plan. Listed below are the five planning documents identified in the RD/RA Work Plan that are required for the performance of the Groundwater RD:

- Site Access and Permitting Plan
- Quality Assurance Project Plan
- Sampling Plan
- Health and Safety Plan
- Predesign Studies Plan

This document was prepared a part of the Predesign Studies Plan (PSP). According to the PSP, Groundwater studies will be conducted as an aid in designing the groundwater extraction and treatment system. The objectives of the groundwater studies are to:

- Determine the extent of VOCs contaminants which are in the groundwater along the west boundary of the WRL Site

- Determine the vertical and horizontal extent of the contaminant plume west of the WRL site.

- Provide information which will optimize the extraction system to remediate groundwater which contains contaminant concentrations above regulatory limits on both sides of Killbuck Creek

The purpose of the PSP is to present detailed descriptions of the testing and field activities associated with these studies. Field efforts will be divided into three phases:

- Groundwater sampling of existing wells (Phase I)
- Placement and sampling of new wells (Phase II)
- Testing aquifer characteristics via a pumping test (Phase III)

This document was written to provide detailed descriptions of the testing and field activities for the Phase III field efforts. This Pumping Test Plan provides a conceptual model for the test and presents a detailed description of the field procedures.

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PUMPING TEST DESCRIPTION

An aquifer pumping test will be performed to collect information necessary to refine the conceptual design of the groundwater extraction and treatment system which was presented in the FS. The test will consist of installing and pumping an extraction well while monitoring water level drawdown in adjacent monitoring wells. Data collected during the test will be analyzed to determine aquifer characteristics (hydraulic conductivity, storage coefficient, transmissivity) necessary for the extraction system design.

As agreed with U.S. EPA, this pumping test will be conducted prior to the 30% complete Remedial Design. This will allow the 30% design to be completed with greater reliability. The extraction well for this test will be located so that it can be incorporated into the groundwater extraction system during RA construction.

2.1 CONCEPTUAL MODEL

Based on data collected during the RI, unconsolidated sand and gravel is present from ground surface to depths ranging from 15 ft below ground surface near the eastern edge of the landfill to over 60 ft below ground surface along the western border of the landfill. The sand and gravel is underlain by fractured dolomite.

Groundwater generally flows from east to west beneath the site. Depth to groundwater varies from one to 2 ft near Killbuck Creek to approximately 15 ft at the western border of the landfill. The water table occurs within the dolomite aquifer beneath the eastern portion of the landfill and is within the sand and gravel beneath the western portion of the landfill. The saturated thickness of the sand and gravel deposits exceeds 45 ft at the western border of the landfill. The sand and gravel deposits are hydraulically connected to the dolomite aquifer.

Potential hydrogeologic boundaries that could influence a pumping test include Killbuck Creek and the dolomite aquifer. Killbuck Creek is located approximately 300 to 1,000 ft west of the landfill and is probably a natural discharge area for some shallow groundwater flow. Based on the RI data, deeper groundwater flow may pass beneath the creek. However with a pumping well near the Creek, it may act as a source of groundwater recharge.

Groundwater contaminants are present in the sand and gravel deposits along the western border of the landfill in the area of the proposed groundwater extraction system. Therefore, it is expected that the extraction wells will be screened primarily in the sand and gravel.

In order to design and conduct a pumping test and evaluate the resulting data, certain assumptions about the aquifer system must be made. In most cases, not all of the assumptions are met in reality. The assumptions used to design this pumping test and any departures from those assumptions are discussed below. The assumptions are:

- The aquifer is unconfined
- The aquifer is infinite in areal extent
- The aquifer is homogeneous and of uniform thickness over the area influenced by the test
- The pumping well fully penetrates the unconsolidated aquifer
- The aquifer will be pumped at a constant rate

In fact, the unconsolidated aquifer pinches out against the dolomite bedrock to the east and the dolomite may act as a boundary in this direction. Therefore the unconsolidated aquifer is not infinite in extent and the saturated thickness is not uniform. However, it is expected that the cone of depression will not extend to this boundary during the pumping test.

We expect the creek will present a partial recharge boundary. It is unknown whether the Creek will have an affect on the pumping test, although the test is setup to measure this affect.

2.2 EXTRACTION WELL LOCATION AND SPECIFICATIONS

One extraction well will be installed for the test. This well will be constructed so that it can be used as part of the final groundwater extraction remedy. The well will be installed west of the Site in the area of highest VOC contamination. In addition, it will be located so that existing monitoring wells can be used for water level measurements during the test. The proposed location is shown on Drawing B4. More specifically, this location would be 50 ft northeast of well nest MW106/P1 (on a line perpendicular to Killbuck Creek). The actual screen interval will be chosen after a test boring is drilled to obtain specific geologic conditions at the extraction well location.

The test borehole will be performed at the proposed well location and split spoon samples will be collected continuously ~~at 2.5 ft intervals~~ from the ground surface ~~water table~~ to 100 ft from ground surface, or bedrock, whichever is less. ~~the proposed depth of the extraction well.~~ The extraction well will be drilled to 70 ft or bedrock, whichever is encountered first. A minimum of two soil samples from each mappable geologic unit will be analyzed for grain size analysis. The results of the grain size analysis will be used for the determination of a proper extraction well screen length and slot size and the need for and size of the filter pack.

The extraction well will be constructed of 6-inch diameter, Sch. 80 PVC well screen and riser. Based on the results of the test boring and grain size analysis, an extraction well will be designed with the estimated yield of 30 to 50 gpm. Entrance velocities are estimated at 0.1 ft/sec. The extraction well will be screened from 30 ft to 70 ft. A 3 ft length of casing will be attached to the base of the screen to act as a sump. The purpose of the sump is to collect fines which may be brought into the well during the pumping test. The extraction well screen and filter pack sizes will be calculated using the procedures identified in Chapter 13 of Groundwater and Wells (Driscoll, 1986). Based on the results of the grain size testing, the existing formation materials may be used as a natural sand pack.

2.3 EXTRACTION WELL INSTALLATION AND DEVELOPMENT

The extraction well design and installation will be completed approximately two to three weeks after completion of the test borehole. The extraction well will be drilled using a method which is least likely to disturb the formation during drilling. Hollow stem auger drilling is the likely method because it will not introduce drilling mud into the formation. Cable tool or rotary drilling methods will also be evaluated. The actual drilling method will be determined based on the test borehole at the extraction well location.

Installation of the extraction well will begin by setting the base of the well (sump) at a predetermined depth and backfilling with sand pack, or allowing the formation to cave around the sump to a depth of 1 ft below the bottom of the screen. The filter pack or natural pack material will then be placed to a depth of 2 ft above the top of the screen. Two feet of fine sand will be placed on top of the filter pack.

A 5 ft bentonite pellet seal will be placed on top of the fine sand. The remainder of the annular space will be sealed with a bentonite slurry or bentonite-cement grout. The top of the well casing will be terminated approximately 2 to 3 ft above ground surface. The top of the well casing must be level to assure accurate top of casing survey data. A pitless adapter with an inductor access port will be installed to allow for measurements during the test. The pitless adapter will facilitate future conversion to an extraction well.

Prior to development, a power source must be in place to run the pump. A high capacity generator may be used as a power supply if continuous power is not available. However, restrictions on fuel capacity, and power fluctuations must be resolved prior to selecting this power source. The preferred power source is a temporary electrical line. The electrical supply must be installed by a certified electrician. Local ordinances will be reviewed to determine requirements for supporting an electrical supply line and any insulation requirements. A wooden panel (3 ft x 4 ft) will be erected approximately 10 ft from the extraction well. The electrician will install a lockable, water proof, breaker panel with a 50 amp breaker for the pump and two 15 amp breakers for two additional electrical sockets to be used for lighting. The electrical line to the breaker box will be ~~240 volt, and~~ either 2 or 3 phase depending on the pump requirements.

The extraction well will be developed by the drilling company that installed the well. Well development should not be performed within 24 hours after installation. The driller will be supplied with a copy of the extraction well borehole log and well construction details prior to mobilization for development. The development method will entail mechanical surging, air jetting, and pumping. A temporary pump will be used for development. Development will be terminated when the specific capacity necessary to pump the desired rate is achieved or when further development does not increase the specific capacity. A detailed procedure for extraction well development, as modified by this Report, is located in Appendix A.

2.4 OBSERVATION WELL LOCATIONS

The extraction well will be located in the northwestern corner of the site where several existing monitoring wells can be utilized as pumping test observation wells. Existing monitoring wells P1, MW106, P3R, P4R, G116, G116A, and G117 will monitored for water levels during the pumping test with data loggers and transducers. Wells G116 and G116A will serve as background wells. Wells located across the Creek from the extraction well were purposely chosen to isolate them with a potential hydraulic boundary. In addition, two temporary water level piezometers will be installed, ~~one half way between~~ approximately 25 ft southwest of well nest MW106/P1 and Killbuck Creek and one 25 ft northeast of the extraction well. Exact locations of wells T1 and T2 will be determined in the field. Steep slopes may require the well locations to be modified. They will be constructed of Schedule 40 PVC and will be screened from 30 ft to 70 ft. ~~screened at the midpoint of the extraction well screen~~. A discussion of the observation well locations in relation to the pumping well is located in Appendix B.

2.5 HANDLING OF EXTRACTED GROUNDWATER

It is expected that approximately 36,000 to 50,000+ gallons of water will be extracted during the pumping test. Water extracted during the pumping test will be discharged into the leachate treatment system, because NPDES permitting will not be completed prior to the test. The extracted groundwater must be trucked to the landfill treatment facility. To avoid interruption of the pumping rate during the test, a 5,000 gallon tanker will be parked next to the extraction well and serve as a temporary holding tank into which all extracted groundwater will be pumped. A mobile truck will remove water from the holding tank as necessary and transport it to the landfill treatment facility. A log will be kept by the trucker on the volume of each load transported to the treatment facility. The log will serve as check on the total volume of groundwater pumped during the test. ~~A sample of the log is included in Appendix C.~~

2.6 PUMPING TEST PROCEDURES

One day prior to the pumping test, a step-drawdown test will be performed. The step-drawdown test will consist of four successive equal time periods of pumping. The pumping rate will be increased for the first three periods, and will be approximately one-third, two-thirds, and equal to that of the constant rate pumping test. Each step will continue until drawdown in the extraction well has stabilized or until it is clear the well cannot maintain this pumping rate. The final step of the test will be to set the pump controls to achieve the desired pumping rate. A temporary pump, supplied by the driller will be used for the step-test and constant rate test. The pump will be rated at 20-45 gpm. Data loggers/transducers in all wells (except background wells G116 and G116A) will be set to collect water levels at 5 minute intervals for the duration of the step test. This data will only be used to assure that the transducers are functioning properly.

The constant rate test will last for approximately 24 hours at a pumping rate of approximately 25 to 35 gallons per minute (gpm). The test will not begin until water levels in the monitoring wells have returned to within ± 0.05 ft of pre-test levels. The pump controls will be adjusted during the test to keep the rate to within ± 2 gpm of the starting rate. Drawdown data will be evaluated in the field before termination of the test to determine whether an extended period of pumping will be necessary. Because of the high permeability of the sand and gravel aquifer, it is anticipated that a 24 hr period will generate sufficient drawdown and radius of influence to adequately determine the aquifer characteristics. After the end of the scheduled pumping test, recovery measurements will be made in wells P1, MW106, P3R, P4R, G116, G116A, ~~and~~ G117, and the two temporary piezometers. The test will be considered complete when water levels have recovered to near pre-test conditions.

Data Loggers in the extraction well and piezometers will be set to the following log/linear schedule for the duration of the constant rate test:

Log Cycle	Elapsed Time	Sample Interval
1	1-20 seconds	0.5 second
2	20-60 seconds	1 second
3	1-10 minutes	12 seconds
4	10-100 minutes	2 minutes
5	100 minutes...	10 minutes

The data loggers in background wells G116 and G116A will remain at a 0.5 hr interval collection interval from pre-test collection through recovery water level collection.

During the constant rate test, manual water level measurements will be obtained from all wells for quality control purposes only. The measurement interval will be logarithmic and will strongly depend on how long each round of manual water levels takes to perform. Staff gauges located in Killbuck Creek will also be included in the manual water level measurements. A detailed description of the pumping test procedures and test preparation, as modified by this report, is located in Appendix B.

2.7 GROUNDWATER QUALITY SAMPLING

Groundwater quality samples will be collected from the extraction well and each well to be monitored in the test (7 wells) prior to the background (pre-test) monitoring period and after completion of the recovery phase of the test. The extraction well discharge will be sampled four times during the constant rate test (at 10 min. 100 min. 1,000 min. and near the end of the test). Each sample will be analyzed to help establish treatment system requirements. All sample handling and analysis will be performed in accordance with the QAPP. Analytes will be as follows:

Pre and Post Test Samples

Extraction Well
- VOCs
- Iron
- Chloride
- Arsenic
- Manganese
- Hardness
- TOC
- TDS
- Dissolved Oxygen
- Carbonate/Bicarbonate Alkalinity

Monitoring Wells
- VOCs
- Iron
- Chloride
- Arsenic
- Manganese
- Hardness
- TOC
- TDS
- Dissolved Oxygen
- Carbonate/Bicarbonate Alkalinity

Pumping Tests Samples

Extraction Well
- VOCs
- Iron
- Chloride
- Arsenic
- Manganese
- Hardness
- TOC
- TDS
- Carbonate/Bicarbonate Alkalinity

Monitoring Wells

Cannot be sampled due to water level monitoring

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DATA ANALYSIS AND REPORTING

Data collected during the pumping test will be analyzed to estimate aquifer transmissivity and storativity. These parameters will be used to design an extraction system and pumping rate that will capture the contaminant plume. It is anticipated that anthe Theis unconfined aquifer analysis method in the "AQTESOLV" software package will be used to analyze the pumping test data. However, boundary conditions or other non-linear influences on the test may require the application of other solution methods or correction factors. A description of the data evaluation and potential analysis methods are located in Appendix B.

The results of the pumping test will be reported in the 30% complete Remedial Design Report.

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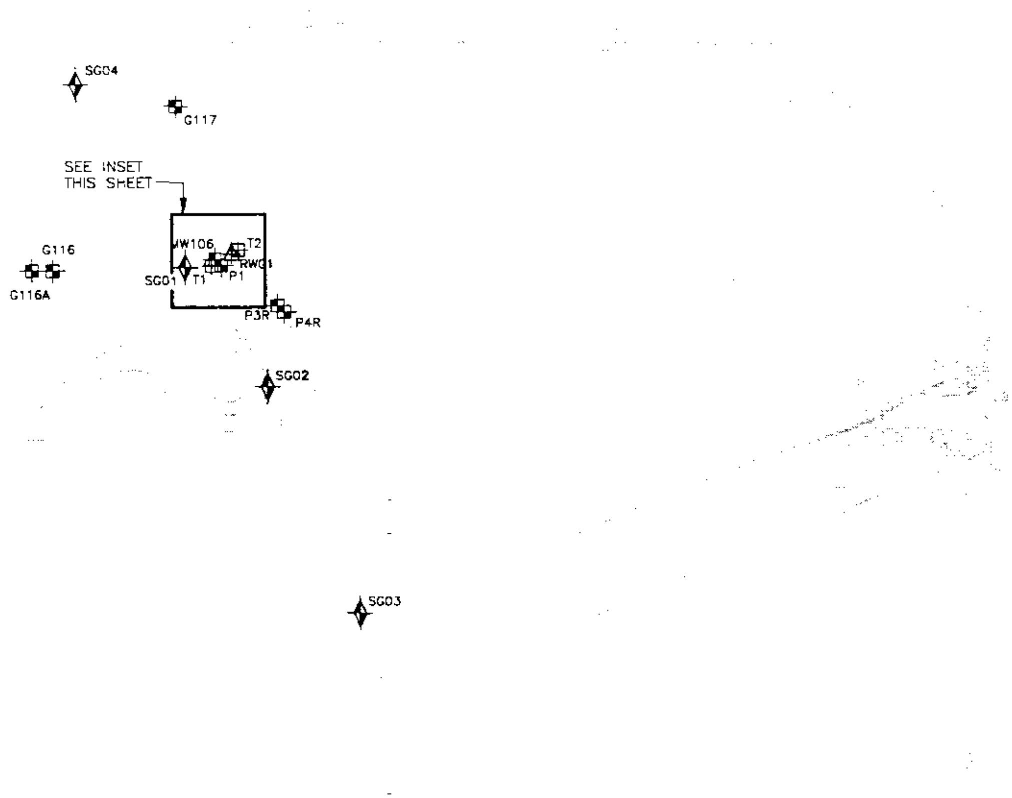
DRAWINGS

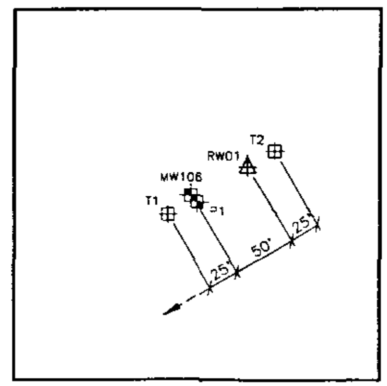


LEGEND

- T2 — PROPOSED MONITORING WELL LOCATION AND NUMBER
- RW01 — PROPOSED EXTRACTION WELL LOCATION AND NUMBER
- SG03 — EXISTING STAFF GAUGE AND NUMBER
- G117 — PUMPING TEST OBSERVATION WELL LOCATION AND NUMBER
- MONITORING WELL LOCATION AND NUMBER
- FENCE

NOTES

1. BASE MAP DEVELOPED FROM AN AERIAL SURVEY MAP PREPARED BY GEONEX-CAS. DATE OF PHOTOGRAPHY: APRIL 26, 1990.
2. THE PUMPING TEST WELLS WILL INCLUDE EXISTING OBSERVATION WELLS P1, MW106, P3R, P4R, G116, G116A, G117, AND PROPOSED WELLS T1 AND T2 AND PROPOSED EXTRACTION WELL RW01.
3. PROPOSED WELL T1 MAY BE MOVED CLOSER TO WELL MW106 IF SIDE SLOPES ARE TOO STEEP TO INSTALL THE WELL 25 FEET FROM MW106.



PUMPING TEST AREA INSET

1" = 100'

north

0 400 800

SCALE IN FEET

PUMPING TEST WELL LOCATION MAP

PUMPING TEST PLAN
WINNEBAGO RECLAMATION LANDFILL SITE
WINNEBAGO COUNTY, ILLINOIS

Developed By: TJK Drawn By: LCL
Approved By: Date: 7-18-94
Reference: 20023601-B15
Revisions:

Drawing Number 20023601 B4

WARZYN

QUALITY CONTROL
Graphic Standards TMS 6-20-94
Lead Professional TJK 6-21-94
Technical Review MJH 6-21-94
Project Manager
Management Review
Other

APPENDICES

A

A

Extraction Well Development SOP

Section Well Installation and Testing	**Section No.** 208	**Date of Issue** June 1994	**Reviewed By** T. Karwoski
Subject Extraction Well Development	**Page of** 1 4	**Date Revised**	**Authorized By** K. Quinn

Scope and Application: This SOP is for the initial development of extraction wells.

References: Groundwater and Wells (Driscoll, 1986).

Procedures

The general procedure for effective development is:

- Begin surging the well with a surge block until sediment production goes down.
- Go to air jetting.
- Go back to surge block or pumping.
- Alternate between surge block, pumping, and jetting.
- Finish by pumping.
- Check and record specific capacity (pumping rate/drawdown in gpm/ft).

The specific procedure for development is:

1. Before beginning development drop a bailer to the bottom of the well and then pump it (quickly raise and lower) to check for sediment. If the well bottom or sump is full of sediment, remove it before starting development (e.g. use a pump installed into the sump or use a bailer).

2. Retain a sample of water and sediment removed from the bottom of the screen. This will be used to document the size fraction of material in the well before development. If development results in breaking the screen (e.g. dropping a string of tools to the bottom, breaking a weld on the base, etc.). allowing coarser grained sediment to come in, this sample would document this coarse grain size was not present before development.

3. Start development with a valved surge block to remove the fines in the immediate vicinity of the screen. The surge block gasket should fit firmly in the well (no space between well casing and gasket, but not so tight to be too difficult to remove). The valve on the surge block should be closed for wells in high permeability sand and gravel. This will allow water and sediment to move upward through the block, but not downward.

   However, in lower permeability soils, opening the valve may be required to allow moving the surge block.

Surge Block Operation:

- Use of a rig with a hydraulic head is more effective with a surge block than with a cable tool rig where the weight of the rod and string only forces the tool down.
- Drillers must check and mark on the rig, the point where the top of the drill rod would put the surge block at the bottom of the well screen.
- Do not lower the surge block into the casing sump below the screen unless the valve is opened or the gasket is loose enough to allow flow past it.
- Start at the bottom of the well screen, raising and lowering the surge block in approximately 2 ft strokes.
- The surging should pull water and sediment into the well on the upstroke. On the downstroke, some sediment and water is forced up through the check valve and some is forced out of the screen. This action loosens the sediment outside the screen and pulls it in on the upstroke.
- Continue operation from the bottom to the top of the screen.
- Contain sediment produced as necessary.

- Collect a sample of sediment once during development and once on completion to compare back to the original, pre-development sample to check for effectiveness of development and for possible screen damage. Note on development form:

  - Grain size, especially note any grains coarser than installed screen size.
  - Color, especially any black or gray bacterial matter (generally only on wells being re-developed).

4. Surging should be followed by air jetting. A jetting tool typically consists of a set of horizontal nozzles, slightly smaller than the well diameter. A dual tube arrangement is available from some contractors that allows jetting through the nozzles or to act as an air lift pump when redirecting the air up the center tube. However, air lift pumping requires approximately 40% to 60% submergence (i.e.(depth below water/total depth)*100) which we typically do not have, except in very shallow groundwater conditions. Pumping at <40% submergence is possible but air is also blown out the bottom of the dual tube.

Air Jetting Operation:

- The objective of air jetting is to apply a large force on the screen, sand pack, and formation to loosen encrustation, precipitates, and sediment for later removal.

- Because an air jet only applies force outward from the screen it is imperative that it be used with another method to pull water and sediment back into the well for removal.

- A dual tube - air jet/air lift pump can do this if submergence conditions are favorable.

- Air jetting should be started with straight air, some water can be injected later for additional force if air alone is not successful.

- Jet each zone of the screen while rotating the nozzles to get full coverage.

- Alternate between jetting and pumping as often as practical but do not jet for more than 3 minutes per foot of screen without pumping.

- After jetting a zone, pump as soon as possible but not more than one hour after jetting.

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B

B

PUMPING TEST SOP

WARZYN INC.

FIELD SAMPLING AND TESTING SOPs and TGDs

Section Well Installation and Testing	**Section No.** 205	**Date of Issue** June 1994	**Reviewed By** T. Karwoski
Subject Pumping Tests	**Page of** 1 8	**Date Revised**	**Authorized By**

Scope and Application: This SOP is for pumping tests in vertical well with water level monitoring at observations wells using pressure transducers and data loggers.

References: Chapter 2 - Pumping Tests of Analysis and Evaluation of Pumping Test Data by Kruseman and DeRidder.

OBSERVATION WELL LOCATIONS AND THEORY

The number of observation wells required for a pumping test depends on the amount of information required. Kruseman and DeRidder (1991) recommend a minimum of three wells so data can be analyzed by both time drawdown and distance drawdown methods.

The distance an observation well is placed from the pumping well depends on the type of aquifer and its transmissivity, duration of pumping, discharge rate, length of well screen, and stratification or fracturing within the aquifer. Generally, wells should be placed so data would be uniformly spaced on a logarithmic scale (e.g., 10, 25, 50, 100, 225). The actual design of the pumping well and monitoring network should be based on a preliminary analysis using a simple well hydraulics equation (e.g., Theis equation) and general information about the aquifer geometry and hydraulic conductivity. For more specifics on observation well placement, refer to pp 33-36 of "Analysis and Evaluation of Pumping Test Data" (Kruseman and DeRidder, 1991).

The depth of the piezometers is also dependent on the type of aquifer. In an isotropic, homogeneous aquifer, the center of the piezometer screens should be placed at the same elevation as the center of the pumping well screen. In heterogeneous, layered aquifers, nests of piezometers and screens intersecting the highest conductivity layers are desired.

PRE TEST PREPARATION

Pumping Test Field Equipment

1. Work Plans and Health and Safety Plans
2. Special field instructions (optional)
3. Electric water level indicator(s)
4. Oil interface probe (if floating oil present)
5. Hermit data loggers(s) - 2-channel and 8-channel
6. Pressure transducers - 1 for the pumping well and each observation well
7. Pressure transducer protectors or hazardous waste pressure transducers
8. Submersible pump (to include all plumbing equipment)
9. In-line totalizing flow meter(s)
10. Sufficient hose or pipe to discharge water outside of test area or to tank/sewer etc.
11. Well head flow meter
12. Time piece (digital)
13. Barometer
14. Electricity supply for well pump (2 or 3 phase depending on pump)
15. Fixed and portable lighting with electricity supply
16. Field computer (to include a spread sheet and AQTESOLV)
17. Groundwater sampling equipment (optional)
18. 2 - 5 gallon bucket
19. Tool box
20. First aide kit

Data Logger and Transducer Evaluation and Programming

The data loggers (2-channel and 8-channel) and transducer(s) to be used to collect data during a pumping test must be evaluated for functionality, accuracy, and drift sufficiently in advance of starting to collect data in order to replace defective transducers. Four days is recommended.

Subsequent to completing the data logger and transducer evaluations each data logger should be programmed for the collection of background water level data. Follow the instructions in the In Situ data logger manuals for the 1000 (2-channel) and 2000 (8-channel) data loggers. Select linear sampling and set the water level sampling rate at one recording every 15 minutes. The "Type" and "Mode" will be set to Level and TOC, respectively, Transducer parameters "SG" and "Delay Msec" will be set to 1.0 and 50.0, respectively. Transducer parameters "linearity", "Scale Factor", and "offset" will be set to the values that are printed on the data tag attached to the transducer cable reel. Use the quadratic coefficients for the linearity. The reference value is the only transducer parameter that must be set in the field. The reference should be set to 0.0 after each transducer has been placed below the water table and the water table has been allowed to stabilize and the temperature of the transducer has been allowed to equilibrate with the current groundwater temperature.

Baseline Data Acquisition Phase of Pumping Test
Pre-pumping test water level, precipitation, and barometric pressure data should be collected for five days in advance of the pumping test. The following field activities are to be performed, in this order, during the first full day of field activities.

1. Collect a complete round of water level measurements.

2. Install the rain gauge and a digital or analog barometer at the pumping test site. Barometric pressure and precipitation will be recorded once each day during the collection of background data. Initial barometric pressure and precipitation readings will be collected at the end of the first full day of field activities.

3. Install transducers in pumping test wells per the Work Plan and field instructions prepared for the site (construct transducer cable protectors, if needed).

   The 8-channel data logger will be used to monitor water levels in as many designated wells as possible. Two channel data loggers will be used to monitor water levels in a well(s) that has/have been designated background. Depressing XD on the data logger as the transducer is lowered down the well will show depth (in feet) below liquid surface. Pressure transducer total depth (TOC) can be determined by adding the XD value and the current depth to liquid (TOC) measurement. When the transducer has been set to the appropriate depth it will be necessary to monitor the XD values for the transducer in order to determine if the static water level has equilibrated. Equilibration will be considered complete when the XD value remains constant to within ±0.02 feet. Also, because transducer readings can be adversely affected by changes in transducer temperature it is imperative that each transducer be allowed to temperature equilibrate with the groundwater for up to 0.5 hours.

After equilibration, set the reference for each transducer to 0.0 and start the data logger. Monitor the data logger by using the view function (refer to pocket guide or manual) for one hour to ensure that the logging equipment is functioning properly.

4. Check the data logger(s) and transducers periodically during the collection of this preliminary data to see that the equipment is functioning properly and to begin plotting and reviewing water level, barometric pressure, and precipitation data. Frequency is dependent on the cost to check vs the cost to lose data and the data quality control needed. One check at the beginning, middle, and end of a 5-day baseline period is generally sufficient. This will require downloading of water level data from the data loggers with a laptop computer (following the instruction contained in-Situ's instruction manuals) and manually collecting a complete round of water levels from pumping test wells. Data values collected for each transducer should be reviewed in order to verify that:

   - The data logger is sampling at the defined sampling rate.
   - The transducer drift is within acceptable tolerance (±0.01 ft)
   - Changes in water level are recorded within acceptable tolerance (±0.01 ft)
   - If the data logger(s) and/or transducer(s) are malfunctioning, replace with a spare. If a spare is not available, contact the project manager immediately.

   Barometric pressure and precipitation measurements should be recorded at least once per day, obtaining hourly records from the nearest recording.

5. Preliminary data collection will be terminated for the 8-channel data logger, typically when the step test or pumping test is to be started. Follow the instructions In-Situ manuals and pocket guides for terminating a test. The background data logger should continue to collect background water level data.

Step Test (Optional)

A step test may be conducted the same day that preliminary data collection is terminated. The purpose of the step test is to determine the maximum pumping rate sustainable by this well. At least three pumping steps are recommended, each lasting 1 to 2 hours. The test can be performed in one day but should be completed at least 24 hours prior to the planned start of the constant rate pumping test to allow time for the water table to recover to near static conditions (12 to 24 hours).

Water levels through time in the pumping well and its pumping rate are the only data needed for the step test. However, this test also allows a final test on pressure transducers in wells near the pumping well.

The pumping in the well is started at a rate of about ⅓ its estimated maximum. Water levels in the pumping well are recorded on about a two to five minute interval.

Drawdown from static is plotted through time. When steady state conditions are reached (i.e., very little additional drawdown is occurring) the pumping rate is increased to the next step.

If drawdown continues to increase, without approaching steady state, and it appears this will dewater the well before the length of time desired for the pumping test, a lower pumping rate should be selected. Caution should be used that a true steady state is reached at this lower rate as opposed to simply a reduced rate of drawdown.

The rate for the pumping test should be determined during the step test to be the highest rate possible that will not dewater the well during the test. The pumping rate should be adjusted to that rate so no adjustments are needed during the critical early time of the pumping test.

Pumping Test
Following completion of the step test or background data collection if no step test is conducted, the 8-channel data logger should be reprogrammed for the pumping test following the instructions in the In-Situ manuals and pocket guide. The data logger should be set for Top of Casing (TOC) mode and logarithmic sampling intervals with conversion to linear sampling at 10 minute intervals after log cycle 4 (refer to In-Situ manuals). Water levels in the aquifer also must be allowed to recover to near pre-step test conditions (within 0.03 ft), allowing for changes in background water levels). This typically will require a 12 to 24 hour period of time.

The reference for each transducer (except those in background wells) should be set to 0.0, start the data logger, and then start the pump (record start time).

The flow rate must be periodically monitored by observing both the in-line and well head flow meter readings and by performing one or two bucket measurements. Bucket measurements are made by recording the time required for the pump discharge to fill a 5-gallon bucket. The rate is then converted to gallons per minute. Carefully make minor pumping rate adjustments as needed to maintain a constant pumping rate. Record actual pumping rates and time of reading.

Manual collection of water levels in pumping test observation wells should be collected at a minimum of 5 times during the test for transducer measurement quality control.

Time and depth to water will be recorded on the forms attached to this document.

Data should be downloaded from the data logger every six to eight hours using the laptop computer, In-Situ's data transfer program (or Kermit) and following downloading procedures detailed in In-Situ's data transfer manual. Be careful to do this without erasing the previously recorded data.

Arrangements should be made with the project hydrogeologist for data transfer (e.g., sending as ASCII file via the VAX and/or on floppy disk overnight mail). A detailed shift report should be maintained for each of the shifts and submitted to the project hydrogeologist on a daily basis (FAX) to include:

- Manual water level measurements
- Associated transducer readings and the time of measurement
- Pumping rate checks and time of check

Downloaded data should be reviewed for quality and consistency and to determine when the full scale pumping test should be terminated and the recovery test initiated.

Recovery Phase
Prior to initiating the recovery phase of the test a final data download must be performed. To initiate the recovery phase the "STEP THE TEST" key sequence (described in the In-Situ manual) should be executed. Simultaneously, the FI key should be depressed (will initiate data collection by the data logger and transducers for the recovery phase) and the pump turned off. Record the time when the recovery phase initiated. Manual water level measurements should be collected from each observation well on the same schedule as during the pumping test for transducer quality control should be monitored (remember that data cannot be viewed until log cycle three is complete).

When pre-pumping test static water level conditions are approached in the pumping well, the recovery phase of the test may be terminated. Stop the data loggers and demobilize from the site. The data loggers should be returned to the office for data downloading into a file on the hard drive of an office personal computer since the file containing the data can be large. Follow the download instructions in In-Situ's Data Transfer Manual. The downloaded data should be copied to a 3.5" high density floppy (compress with PKZIP if necessary) which is to be provided to the project hydrogeologist.

Data Evaluation
After completion of all four phases of the pumping test (background, step-test, constant rate test, recovery), the following procedures should be followed to perform data analysis:

1. Download the data onto a PC computer by following the directions in the data logger manuals.

2. Make at least one extra file copy of the raw data before erasing the data logger entries.

3. Create a working copy of the files and transfer them into "Excel" Spreadsheet format. (.XLs). Parse the data into time and drawdown columns.

4. Plot the background, constant rate, and recovery data on log and semi-log scales.

5. Review the plots for the following:

   - Instrument drift (compare each plot to background well plot).

   - Unidirectional variation (influences by natural recharge or discharge).

   - Rhythmic fluctuations (aquifers can be influenced by changes in tides, river levels, atmospheric pressure).

   - Non-Rhythmic Regular Fluctuations (changes in barometric pressure).

   - Unique fluctuations (heavy rainfall, sudden rise in river levels). Refer to pp 47-48 of Analysis and Evaluation of Pumping Test data (Kruseman and DeRidder, 1990) to determine how to correct for these data variations.

6. Interpretation of the data can now be performed. There are many methods which may be applied to interpret a pumping test. The specific methods applied to any one test depend on:

   - Aquifer type
   - Well response
   - Boundary conditions

There are several published methods in Kruseman and DeRidder (1990) as well as in the "AQTESOLV" Software.

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FORMS

WARZYN

DIRECT MEASUREMENT DATA COLLECTION FORM

Job Name ______________________ Well No. ______________________

By: ______________________ Job No. ______________________

Date: ______________________ Sheet No. 1 of ______

Depth to Water: ______________________ ft

Clock Time	Elapsed Time	Depth Measurement (ft)	Comment